Farmers' Bulletin 1234
United States Department of Agriculture

GULLIES—How to control *and* reclaim them

GULLYING occurs in every State in the Union. Besides ruining fertile land, gullies interfere with farm operations, undermine buildings, encroach on public highways, endanger the life of stock, and often mar the beauty and lower the market value of a farm. They are also largely responsible for the filling up of reservoirs, streams, and dredged channels, and for the covering of bottom lands with deposits of sand.

Gullies can be prevented by increasing the absorptive capacity of the soil, protecting the surface from erosion, and conducting the surplus water from the field at a low velocity. Gullies can be reclaimed by plowing-in and seeding to grass or timber, or by building soil-saving dams that check erosion and cause the filling of the gully with silt above the dams.

It is recommended that this bulletin be read in conjunction with Farmers' Bulletin 997, Terracing Farm Lands.

Contribution from the Bureau of Public Roads

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Washington, D. C. February, 1922

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GULLIES: HOW TO CONTROL AND RECLAIM THEM.

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OCCURRENCE OF GULLIES.

GULLYING occurs in every State in the Union. The Southern States have suffered heavily from gully erosion, as the annual rainfall is large and a large proportion of the land has been devoted year after year to the production of clean-cultured crops, such as cotton, corn, and tobacco.

Gullies are of common occurrence on northern farms also; in many localities they are a serious menace. In a typical case a main gully and its many branches, 15 to 20 feet deep and 30 to 60 feet wide, extended over and cut up into small areas an 80-acre farm, and expensive concrete structures were required to prevent the gully from crossing two highways. The land, practically ruined for farming, would be worth $300 or $400 per acre to-day were it not for the gullies. An old resident stated that 25 years ago there was not a gully on this farm.

RESULTS OF GULLYING.

The worst damage done by gullies is the ruining of fertile farm land through the irredeemable loss of good, fertile soil. Other objections to gullies are:

They can not be readily crossed with teams and farm implements.

They form a channel for the rapid removal of fertile soil brought down by surface erosion from the tributary drainage area.

They grow rapidly and often extend through a farmer's premises, undermining and necessitating the removal of residence and outbuildings (fig. 1).

They encroach upon public highways paralleling them and make travel unsafe.

They extend across roadways and undermine bridge structures (fig. 2) often necessitating the building of long and high bridges.

They cause the filling up of reservoirs, river channels, and dredged channels made at great expense (fig. 3).

They furnish most of the sand that is washed from hills and deposited on rich bottom land, making it unproductive (fig. 4).

They present an unsightly appearance and often mar the beauty of a farm, reducing its market value and the value of adjoining farms.

They endanger the life of stock that graze too near the edge of undermined banks.

CAUSES AND TYPES OF GULLIES.

Gullies are caused by erosion due to water collecting and flowing at a velocity sufficient to move and carry away soil particles.

HEAD EROSION.

When plants and soil are unable to retain all of the rain that falls on rolling or hilly land the surplus flows over the surface to a drainage channel at the foot of the slope. If there are no draws or depressions the water travels over the surface to the foot of the slope in broad, thin sheets. Where depressions exist, however, the water is led into the depressions. It gathers from above and from the sides of the depression and forms a stream with power to wash away the soil proportional to the stream's size and velocity. If the depression is not sufficiently protected by grass or other means to prevent erosion, a gully begins to form which enlarges with each succeeding rain.

Natural hollows are not the only places where gullies start. They may start at any place on a slope where opportunity is afforded by artificial means for the water to collect and form a small stream. Driving a wagon down a slope when the ground is soft leaves wagon tracks that may later develop into gullies (fig. 5). A gully may be started by dragging a plow down a slope. Mole holes and cattle paths down a slope are common causes of gullies. One of the commonest ways to start gullies is to plow or cultivate straight up and down a slope (fig. 6). A dead furrow extending down a slope may rapidly develop into a deep gully.

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FIG. 1.—Gully encroaching on farmer's premises which unless controlled will undermine the buildings. Near Alma, Wis.

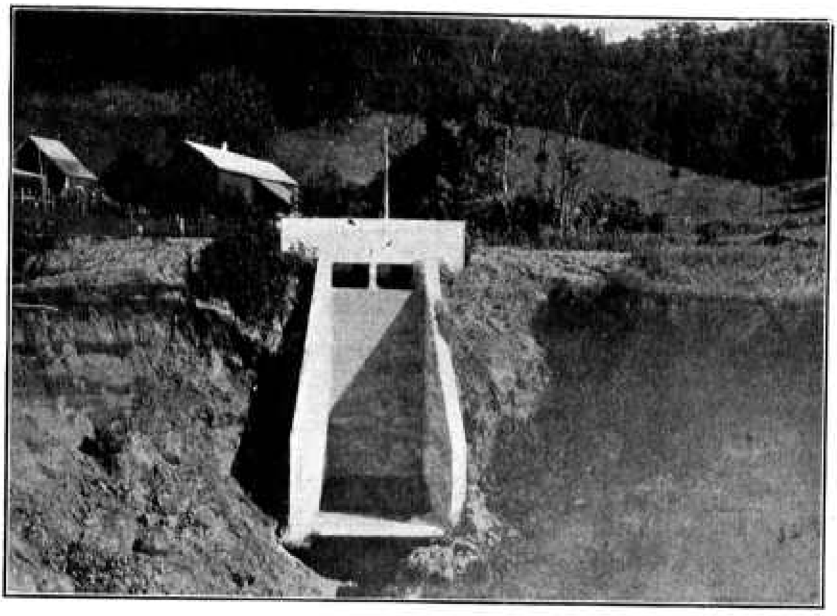

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FIG. 2.—Road culvert and concrete drop inlet built at great expense to prevent gully from crossing the highway. It is shown partly undermined and later was washed out. Near Alma, Wis.

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FIG. 3.—Channel nearly filled with sand washed from adjoining hills, requiring dredging at great expense to provide drainage for the bottom lands. Gwinnett County, Ga.

DITCH EROSION.

Where head erosion occurs on the upper part of a watershed it makes channels for the rapid removal of the excess water from the field slopes and delivers the water in large volumes to the natural drainage channels at the foot of the slopes. The capacity of these channels is overtaxed by the quick delivery of the water from all parts of their watersheds, and the result is that the channels are greatly enlarged by the erosive action of the water. This enlargement continues until huge gullies are formed, often 15 to 20 or more feet deep. The enlargement due to ditch erosion is very rapid on the upper parts of the watershed, where the slopes are comparatively steep. Ditch erosion generally decreases downstream as the fall of

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FIG. 4.—Part of cornfield covered with sand washed from hillside gullies, the result of one heavy rain. Near Jackson, Tenn.

the channel becomes less, and the fall often becomes so slight that silting occurs instead of erosion, particularly where the channel extends across a wide bottom and discharges into another stream.

WATERFALL EROSION.

Waterfall erosion, which is responsible for many of the deepest gullies or chasms, is caused by the falling of water over the edge of a bank of a gully or ditch. The edge is washed away and caves in, owing to the undermining action of the falling water, and the waterfall moves back upstream. The undermining goes on rapidly when sand or easily eroded subsoil saturated with seepage water

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FIG. 5.—The beginning of a gully down a hillside caused by the passing of a wagon once down the slope, if not controlled, destined soon to be a large gully. Near Jackson, Tenn.

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FIG. 6.—Gullies on a hillside due to running cotton rows directly up and down the slope. Near Jackson, Tenn.

underlies the surface soil. These gullies often start in the banks of natural watercourses which have been eroded to a great depth. They extend back into the land slopes and grow deeper up the slope, often attaining depths of 50 to 60 feet. As they extend backward and cross tributary watercourses or natural depressions, waterfalls are in turn formed in their sides and branch gullies develop (fig. 7). This branching may continue until a network of gullies covers the entire watershed. Gullies formed by waterfall erosion may extend back through almost level land. Their growth is dependent upon the size of the drainage area furnishing water and not upon the slope of the land. They sometimes grow at the rate of 30 to 50 feet

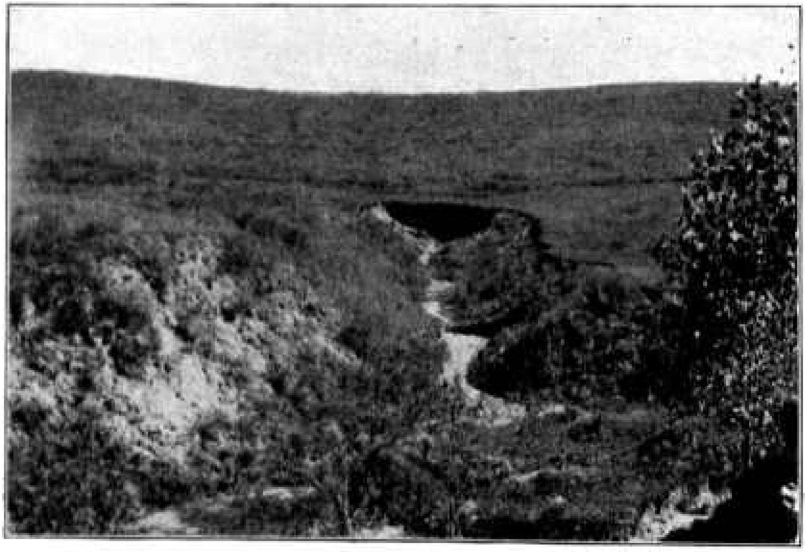

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FIG. 7.—Gully branching off from main gully and advancing up a hillside, growing in depth as it eats its way. Note the undermining of the bank at its head. Near Alma, Wis.

in a year, depending upon the amount of rainfall and the drainage area.

EROSION BY FREEZING AND THAWING.

Another type of erosion, common throughout the South, is caused by alternate freezing and thawing followed by heavy rains. It works on all slopes of a gully bank and does not necessarily follow watercourses. Owing to its capacity to extend in all directions, erosion of this type expands over wide areas, its direction of growth not being dependent upon the slopes of a field. It progresses rapidly, particularly in light silty or sandy soils (fig. 8).

PREVENTION OF GULLYING.

If the farmer could have foreseen the results of failing to spend an hour or two in checking the beginning of a gully such as is started

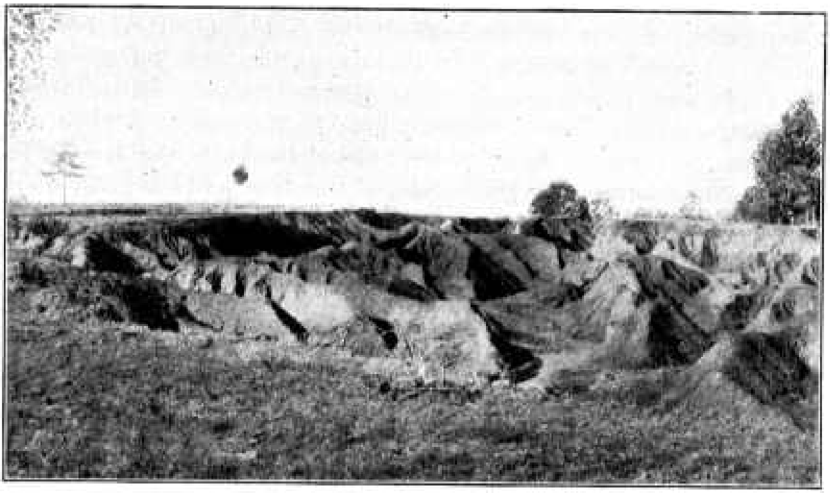

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FIG. 8.—Gullied area on moderate slope growing larger each year. A type of gullying due largely to freezing and thawing followed by heavy rains. Near Middletown, Tenn.

from a wagon track down a hillside, many of our largest gullies would never have been formed. A stitch in time saves many times nine. Gullies from head erosion could be prevented if each square foot of the field slopes could be made to absorb all of the rain that falls upon it. The water would then be fed slowly to the main watercourse below, thus precluding the formation of a deep gully with its numerous deep branches of the waterfall type. Means employed to this end are: increasing the humus content of the soil, deep plowing, the use of cover crops, proper crop rotation, contour plowing, and tile draining.

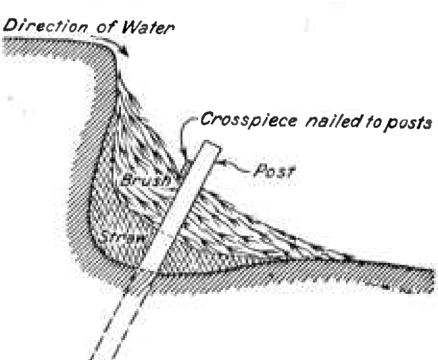

FIG. 9.—Method of checking erosion and undermining at the head of a gulley by brush and straw held firmly in place.[1]

It is, of course, impossible to make any soil absorb all the water from the heaviest rains, and in order to prevent erosion the excess water should be conducted from the field at a low velocity. This can be most effectively done by terracing the land. Farmers' Bulletin 997 covers in detail the practice of terracing farm lands.

[1] From Bul. 74 of the Iowa State College Agr. Ext. Dept.

CHECKING HEAD EROSION.

No matter what method is adopted for control and reclamation of a gully, it is first of all important that erosion at the head of the gully be checked. Where possible it is advisable to intercept the water before it enters at the head of the gully and divert it into a natural watercourse nearby. In shallow gullies, 3 or 4 feet deep at the upper end, head erosion can be checked quickly by building a low obstruction or dam close to the head of the gully. A fill of soil will occur between the dam and the head of the gully, the drop of the water will be reduced by the height of the dam, and the erosive and undermining action of the water will be greatly decreased at the head

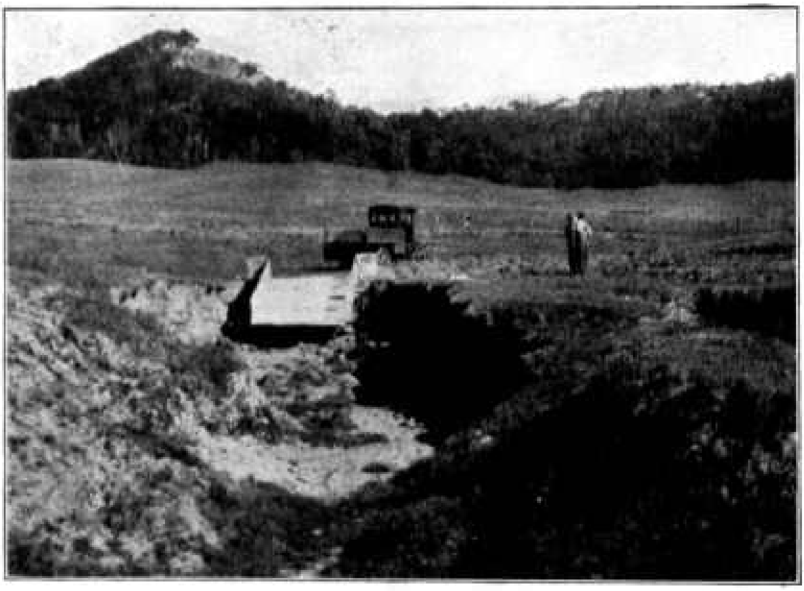

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FIG. 10.—Water conducted into head of gully by levee and a sheet metal flume, the left-hand levee not yet built; brush and stone to be placed at the lower end of the flume. Near Alma, Wis.

of the gully. If the gully is deep, a comparatively longer time will be required to fill it, whatever method is employed, and during the filling some temporary means should be employed to stop erosion and undermining at the head of the gully.

A method of checking head erosion that is widely used in Iowa consists in placing brush and straw in the head of the gully and fastening it down as shown in figure 9. Posts should be set deep in the ground, close to the bank of the gully, and 2 to 3 feet apart. Fence posts can be used for this purpose. A layer of straw is first thoroughly packed around the posts and against the eroded and undermined part of the gully bank. A few branches are laid crosswise and interwoven between the posts to hold the straw in place.

Brush is packed down over the straw, the tops of the branches extending nearly to the top of the gully bank, and is held in place by the crosspiece nailed to the post as shown in figure 9. This affords a place for the water to fall without causing erosion and stops the progress of the gully by preventing undermining until the gully is filled by other methods.

In figure 10 is shown a sheet-metal flume at the head of a gully. The water is conducted into the flume between earth dykes. This flume is intended for use until the gully can be filled by means of dams constructed below. Some sort of protection is generally required at the lower end of the flume to prevent washing.

NATURAL CONTROL AND RECLAMATION.

Nature's method of controlling gullies is to prevent erosion on the surface by the growth of vegetation and to hold the soil together by the plant-root systems. The dead organic matter which accumulates on the surface of the soil from year to year prevents surface erosion and absorbs much of the rainfall. Nature can control gullies, but the natural process of reclaiming them after they are formed is very slow.

After eroded and badly gullied land has been abandoned a volunteer growth of some sort usually springs up. The kind of growth depends upon the locality. Wild native grasses, weeds, shrubs, and trees are the most thrifty and best for rapid and permanent control of the gullies. In some sections pine trees spring up spontaneously over eroded areas and in conjunction with weeds and grasses form a good natural control. Wild honeysuckle grows and spreads rapidly on poor soils and is one of the most effective plants of natural growth in controlling erosion. On account of its tendency to spread, however, other plants are preferred by some farmers. Large gullies with steep caving banks are the most difficult to control by natural means. Their erosion generally continues for many years after the land has been abandoned. Large trees figure prominently in the control of such gullies. The best natural control is where soil is supplied with both nitrogen and humus by the plant growth, so that if the land is ever reclaimed for agriculture it will possess the essential elements of fertility. The black locust and sweet clover furnish nitrogen to the soil and have large, branching root systems, efficacious factors in the control and reclamation of gullies.

In Pendleton County, Ky., large eroded areas of abandoned lands have been reclaimed by the volunteer growth of sweet clover. When sweet clover made its first appearance in the county it was regarded as a weed of the worst kind because of its big root system and prolific growth. Many farmers who formerly devoted much

time to ridding their places of this plant now gather the seed and sow it on their worn-out gullied lands, having noted the large crops grown on abandoned lands reclaimed by the volunteer growth of sweet clover. Sweet clover[1] is a biennial plant. A large root is formed the first year, from which springs the second year's growth. In the second year the plant goes to seed and the root dies. The plant thus reseeds itself, and the decayed roots furnish nitrogen and humus to the soil in addition to making the soil more permeable. Sweet clover is a profitable crop, as it makes excellent hay and furnishes good pasture. It grows well in both Northern and Southern States, but requires a certain amount of lime for rapid and luxuriant growth. Its remarkable growth in Pendleton County can be attributed largely to the plentiful supply of lime available in the soil.

PLOWING-IN AND SEEDING GULLIES.

Plowing-in and seeding is a simple though sometimes rather expensive method of reclaiming gullies. It is applicable to both large and small gullies with small drainage areas and has been successful in all sections of the United States.

In the reclamation of a gullied hillside where gullies are small (1 to 3 feet deep) and have no well-defined drainage areas they should be entirely filled. They can be first partly filled with manure, straw, corn stalks, or small brush, which should be covered with a foot or more of dirt by plowing and scraping in the edges of the gullies. If it is not desired to cultivate the hillside, erosion may be largely prevented by seeding and keeping the land in meadow or pasture, or by devoting it to the growth of timber. If the land is to be cultivated it should first be terraced.

For shallow gullies, or deep gullies with gently sloping banks, the plowing is begun in the bottom of the gully or as near the bottom as possible. The dirt is thrown toward the center of the gully from both sides. The plowing is done in the same way as in breaking land and is continued a few furrows beyond both edges of the gully. To push the dirt toward the center of the gully, an ordinary road drag or steel ditcher can be used to advantage after each furrow. If the upper part of the side slope is steep it is cut down and rounded off with a mattock. In case sufficient dirt has not been moved into the gully after the first plowing, the plowing may be repeated until the desired filling is obtained. If the side slopes are too steep for a team to walk on, a chain hitch to the plow should be made, which will permit plowing on the slope when the team is on the edge of the gully.

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[1] For information on sweet clover see Farmers' Bulletins 485 and 820.

In plowing-in a deep gully with nearly vertical banks the team is made to walk as close to the edge of the gully as possible, and the upper edge of the bank is plowed into the gully. The second furrow cuts the first deeper and the third takes another slice below the second. A long chain is attached to the plow so that it can be operated down in the gully while the team walks along the upper edge.

After the first line of furrows has reached as far down as the plow can be operated, the process is repeated by starting at the top again, the object being to reduce the side slope of the gully. If the gully be not too deep the side slopes can be so reduced in a short time that the team can walk up and down the slopes and across the gully. The team and a scraper can then be used further to reduce the side slopes and distribute part of the soil over the bottom of the gully, or the method described for gullies with gently sloping banks can be employed.

The freshly plowed earth over the sides and bottom of the gully affords a good seed bed for plant growth. Grasses should be sowed or trees planted to hold the soil in place, and temporary dams of some material such as brush or straw should be built to catch the loose soil that might otherwise be washed away by heavy rains. Some of the grasses that can be used for this purpose are Bermuda grass, orchard grass, blue grass, redtop, sweet clover, and lespedeza. Every locality has certain grasses best suited to it. Bermuda is probably one of the best grasses for southern conditions, and it provides excellent pasture for stock. Wild honeysuckle grows luxuriantly in the South on almost barren soils. A more rapid growth can be obtained in gullies by applying elements of fertility in which the soil is deficient. Manure will supply the required elements in most soils. Sorghum is very effective in controlling erosion in gullies.

On the State agricultural experiment station farm near Holly Springs, Miss., some very badly gullied lands were reclaimed by the plowing-in and filling method. Gullied areas of the type shown in figure 8 were reclaimed on this farm. The filled-in gullies were seeded to lespedeza or to Bermuda grass. Most of the land was then terraced so as to keep the water from flowing down through the gullies. In some instances, on this farm and others, dynamite was used to advantage in leveling down and filling gullies. The banks were broken down and blown into the ditch by placing explosives in a row of holes 2 to 4 feet from the edge of the gully, depending upon its depth, or in a row of horizontal holes in the sides and near the bottom of the gully. The first method is preferable for gullies with broad, sloping banks and the second for gullies with high, steep banks.

TILING AND PLOWING-IN GULLIES.

In connection with plowing-in, further erosion is sometimes prevented in a gully by the use of tile. Large tile, the size depending upon the area drained by the gully, is laid down the middle of the gully. The water may be conducted into the tile from a catch basin at the upper end of the gully or by building a dam across the gully and extending the tile through the dam.

PLANTING TREES TO CONTROL GULLYING.

In many localities gullying has been effectively checked by the planting of trees. This method is particularly adapted to land that is very steep or that has been gullied so badly that the cost of reclaiming it for pasture or cultivation would be prohibitive. In addition to building up the land the wood lot thus formed may be made a paying investment to the farmer, furnishing firewood and small timbers. In the South the black locust is an excellent tree for this use. North of the Kansas-Nebraska line it is very commonly attacked and destroyed by the locust borer. The black locust is a legume, and builds up soil by contributing nitrogen. It has a large interlacing root system which holds the soil particles together and prevents washing. It grows to the size of a good fence post in about 10 years, and is especially adapted for posts on account of the durability of its wood. Other trees[1] that are used in different sections for planting on eroded areas are pine, catalpa, yellow poplar (tulip), walnut, and red and black oak.

In planting trees on gullied and eroded areas the best results are obtained by plowing the entire gully and thoroughly disking or harrowing the ground. The trees should be set out in rows 5 to 6 feet apart in deeply plowed furrows. The rows on the sides of the gully should be laid out approximately on the level, as the trees should be cultivated the first year by throwing the dirt from each side toward the trees. Less washing occurs where the rows closely follow the contour of the ground. It is very important that the soil bed be properly prepared, as this will promote a rapid growth of the trees, and the trees are less likely to die at the start.

The best results are obtained where some kind of dam is built across the gully to catch and hold any soil that otherwise would be carried away in the drainage water. Brush dams are commonly used for this purpose; before they rot out the tree root systems will have extended so as to prevent serious washing (fig. 11). It is also a good

[1] For a list of trees adapted for use in the various sections of the United States the reader is referred to Farmers' Bulletin 711, "Care and Improvement of the Wood Lot."

plan to sow grass seed between the trees after setting them out. This grass should not be pastured, or at least close pasturing should be avoided, as it greatly retards reclamation. Where a thicket of locust is desired and not much importance is attached to the use of the trees for posts the tress are sometimes cut down after the first year; this results in sprouts springing up between the tree rows. A dense growth results, which is more effective in checking erosion.

In many instances willows have proved effective in checking erosion in a gully. They should be set out at intervals in rows across the gully. For rapid growth, however, they depend upon an abundance of water.[1]

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FIG. 11.—Gully formerly deep with steep banks reclaimed by locust trees and brush dams. Near Martin, Tenn.

SOIL-SAVING DAMS FOR GULLIES.

The most common method of controlling or filling in and reclaiming gullies consists in building soil-saving dams across the gullies.

Dams may be built of a variety of materials. Temporary dams are built of stakes, brush, straw, logs, loose rock, or woven wire, while permanent dams are built of earth, masonry, or concrete. The cost of building dams is often very little where use is made of material available on the farm. Stones are a nuisance in a field, but they are excellent material for dams. Where no stones are available timber and brush may be plentiful and log and brush dams may be

[1] For information on setting out and caring for trees the reader is referred to publications of the Forest Service, U. S. Department of Agriculture.

built at small expense. Where none of the above materials is available straw may be abundant and can be employed with stakes to build low dams. Woven-wire fencing can be obtained at small cost in any locality and is an excellent material for low dams.

Most temporary dams are porous; that is, when first built they permit the water and part of the silt to pass through them. They are gradually built up by the filling of the pore spaces with trash and soil brought down by the water and are never subjected to the heavy pressure exerted on a water-tight dam from the water ponded above.

Most permanent dams are water-tight, and in order to pass from the upper to the lower side of the dam the water must either flow over or be diverted around the dam or be carried through it by a conduit. If the water is to be permitted to flow over the dam, a spillway of nonerosible material is provided, generally at the middle of the dam, and it should be wide and deep enough to remove the greatest flow of water expected. If the water is to be diverted around the ends of the dam, it is generally made to flow over firm, sodded ground. Sometimes a shallow channel is dug for carrying the water around the end of the dam and emptying it into the gully at a considerable distance below. If the water is to be passed through the dam, it is carried in a pipe.

The inlet consists of a vertical pipe connected to a horizontal line of pipe extending through the dam along the bottom of the gully. The top of the inlet is lower than the top of the dam and the water ponded above the dam does not flow out until it reaches the level of the top of the inlet pipe. The pond above the dam practically forms a sedimentation basin, as the silt in the water settles to the bottom of the pond and in time fills the gully to the top of the inlet pipe. A dam of this kind is sometimes called the drop-inlet soil-saving dam, from its vertical inlet pipe. It is known throughout the State of Missouri as the Adams soil-saving dam, as it is said to have been originated more than 30 years ago by J. A. Adams, a pioneer farmer of Johnson County, Mo. Mr. Adams has five of these dams on his farm, all of which have successfully filled and reclaimed gullies.

LOOSE-STRAW DAM.

In some localities it is not unusual to see a stack of straw forming a dam across a deep, wide gully. Where the threshing of grain is done near a large gully the straw can be placed directly in the gully by the machine. This method is very successful for large gullies with very small drainage areas and little fall. Where considerable water flows through a gully the straw dam is likely to be washed out or a channel washed around the end of the dam. The chances of failure

can be reduced by building the dam high at the sides and low in the middle, so that if all the water does not seep through the straw it will flow over the top of the dam at the middle.

The first straw dam should be built near the mouth of the gully so as to catch all the soil that is being carried away by the water. At the same time provision should be made to stop waterfall erosion at the head of the gully. After as much soil has been filled in above the first dam as it is thought can be held by the sod seeded there when the straw rots out, another straw dam should be built farther up the gully a short distance, and then another until the gully is filled in as desired.

This is a simple and easy method of reclaiming certain types of gullies, but it depends on the availability of a large quantity of straw. With more time and labor to be devoted to the work a more economical use can be made of the straw in building brush, straw, and stake dams, as described later.

Further washing of small shallow gullies is sometimes prevented by filling them with loose straw during the fall and winter. The water percolates through the straw, the silt in the water being retained. In the following spring the partly rotted straw is generally covered by plowing-in the gullies, thus adding to the fertility, and increasing the humus content and the absorptive capacity of the soil. On steep slopes or where the quantity of water reaching the gullies is large, this method is not a success, since the straw is usually carried to the foot of the slope by the force of the water.

WOODEN-STAKE DAM.

A cheap method of filling-in and reclaiming gullies of moderate slopes and small drainage areas consists in driving several rows of stakes across the gully in checkerboard fashion. The stakes should be 3 to 7 feet long with a diameter of 2 to 4 inches at the upper end. The distance between the rows of stakes should be from 6 inches to 2 feet, and the distance between the stakes in the rows, the same. The stakes should be driven into the ground until the tops extend 8 to 20 inches above the surface; the larger and longer the stake the greater may be the distance between the rows and stakes. The rows of stakes should extend across the gully and up the sides as high as water ever reaches in the gully, and the height of the tops of the stakes on the sides of the gully should be at least 1 foot higher than the tops of the stakes in the middle. The stakes may be made of any available hard wood. Where stones are available the dam can be made more substantial by filling in the spaces between the stakes with them, as shown in the three lower dams in figure 12.

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Where stone is not available the ability of the stakes to check and hold silt can be increased by filling in straw between them. A series of such dams should be built along the entire length of the gully, the distance between them being such that each dam will cause a deposit of silt extending to the next above. As soon as the filling in above the first series of dams is completed other dams should be built between the first ones and the filling-in process continued by additional dams until the gully is filled as desired.

BRUSH DAM.

In localities where timber and brush are abundant excellent results have been obtained by the use of brush dams. The methods employed in building these dams vary somewhat in different sections of the country. In hillside gullies where the flow of water is small the dams are commonly built of loose brush sometimes weighted down with logs. Where the flow is sufficient to overtop the dam the brush can be held down by crosspieces and stakes, or the dams are sometimes built by weaving brush into a row of stakes across the gully. Successful results can not be obtained by simply dumping the brush into the gully.

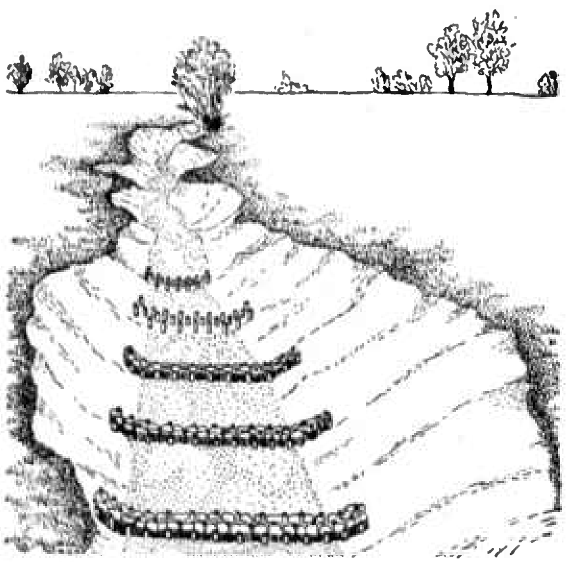


FIG. 12.—A series of stake dams in a gully. The spaces between the stakes in the three lower dams are filled with stones.

In connection with reforestation of gullied lands in Tennessee the State forester, R. S. Maddox, has used loose-brush dams extensively. The dams are built to catch and hold soil in the gullies until the planted trees are able to hold the soil against erosion.

The method of Mr. Maddox is as follows: Trees are first dragged to the site of the gullies, and the branches are cut off. Several layers of branches with the tops pointing downstream are first laid for the foundation of the dam. This is to prevent slipping, as the greater

part of the dam is built with the branches extending crosswise of the gully. The dam is built up by laying the branches close together across the gully, but occasionally a layer of branches is placed with the tops pointing upstream and extending beyond the face. When these branches become covered with silt they tend to hold the dam more securely in place and tie the brush together. After the dam is built about 3 feet high, logs furnished by the trunks of the trees are laid across on top of the brush lengthwise of the dam to hold it down. The dams are built lower in the middle so that the water will flow over the middle of the dam and prevent washing around the ends. Dams built in this manner can be used only where the drainage area of the gully is very small; where there is a large flow of water they are likely to be floated away or washed out (fig. 11).

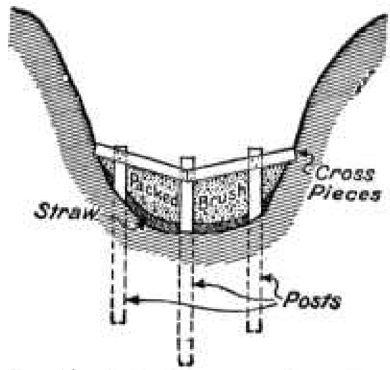


FIG. 13.—Straw and brush dam held in place by the crosspieces and posts.[1]

Where the water in a gully is sufficient to overtop a brush dam it is necessary to anchor the dam more securely. M. H. Hoffman and A. W. Turner, of the Iowa State College extension department, who have had a wide experience in building brush dams, recommend the following method for building brush dams that are at times overflowed: The bottom and sides of the gully for a distance of 4 to 10 feet are covered with a layer of straw that will be from 4 to 6 inches deep after being pressed down by the weight of the dam. The brush, with the butts pointing upstream, is laid close together on the straw and thoroughly tramped down, the fine brush being placed at the bottom and the coarser on top. The packed brush is held in place by crosspieces nailed to fence posts set in the line of the dam across the

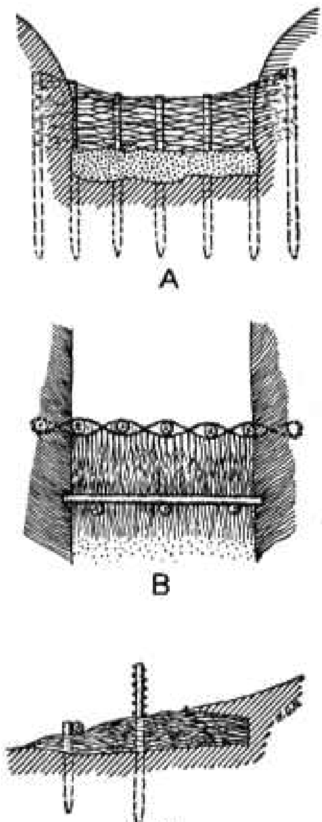


FIG. 14.—A woven-willow brush dam. *A*, Front view. *B*, Top view. *C*, Side view.

[1] From Bul. 77 of the Iowa State College Agr. Ext. Dept.

gully, as shown in figure 13. It is important that the fence posts be well set in the ground, usually not less than 4 feet deep. The figure shows the middle of the dam lower than the sides so that the water will not have a tendency to wash around the ends.

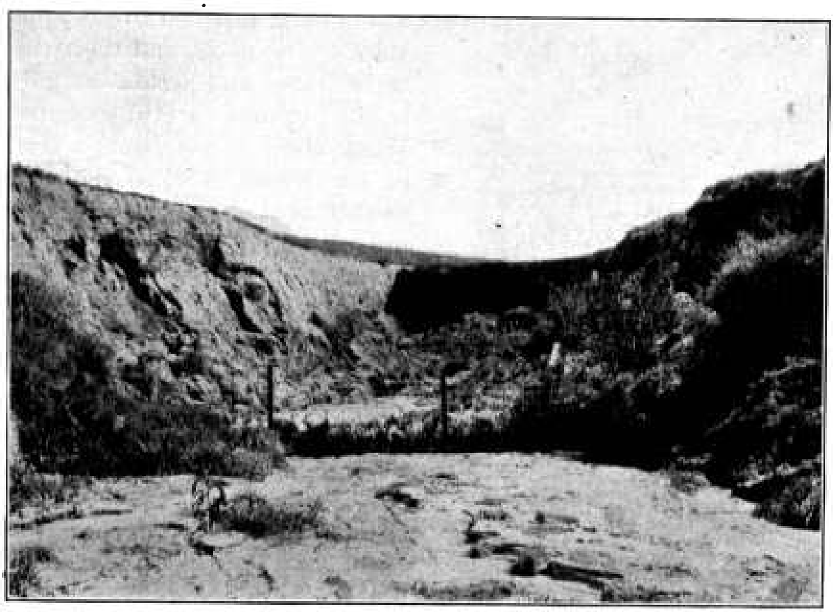
In Europe woven-willow dams, sometimes called wattled dams, are rather common and have proved very satisfactory. Live willow stakes about 3 or 4 inches in diameter and 3 to 5 feet long are driven in a row across the gully about 6 inches apart so that the tops are about 1½ feet above the ground. The row of stakes should extend as far up the sides of the gully as the highest water, and the middle of the dam should be lower than the sides. The stakes are held together by weaving willow branches between them from top to bottom. As shown in figure 14, a brush apron is made below the dam to prevent underwashing by the water flowing over the dam. This apron is built of branches 6 to 8 feet long laid lengthwise of the gully in a trench about half a foot deep. The butts of the branches are laid upstream and are partly buried in the bottom of the gully, and the downstream ends of the branches are held down by a pole laid across them and spiked to a second row of stakes about 3 feet from the first row. The wattled dam is used to some extent in this country. Pine branches are sometimes used in place of willows.

Another form of brush dam, very common in Europe, is the fascine dam. It is made of bundles of brushwood 8 inches to 2 feet in diameter and from 7 to 14 feet long. The bundles are tied together in several places with wire. They are laid with their length across the gully and rest against a row of posts set about 3 feet apart. The posts are of the size of ordinary fence posts and are driven or set into the ground at least 4 feet. The bundles are held in place by driving stakes through their centers 1 to 2 feet apart. Trenches are dug into the sides of the gully, and the ends of the bundles are extended into them to prevent washing around the ends of the dam. The top of the dam is made lower in the middle, and an apron of brush to prevent undermining is built below the dam in the manner described for the woven-brush dam. The height of the dam at the middle is 1½ to 2½ feet.

The brush dam is cheap and easy to build and is effective in filling gullies when carefully and properly constructed. For this reason it is popular among farmers and is employed to some extent in every section of the United States where timber is available. It is best suited for gullies with small drainage areas.

When a farmer has a large quantity of brush to dispose of, a very common practice is to fill large, deep gullies for their whole length with brush which is thoroughly tramped down. When the whole gully is filled it is practically impossible for the force of the water

to move the brush and the silt is caught and held by the brush as the water flows through. Sometimes sections 20 to 50 feet in length are filled solid with brush at intervals along the gully. The huge dams of brush eventually cause the filling of the gully between. Another practice is to shingle the bottom of the gully with brush (as the roof of a house is shingled), commencing at the lower end of the gully and laying the brush with the tops pointing upstream. If the water is likely to displace the brush it can be held in place by crosspieces fastened to stakes at intervals along the gully. Leaves scattered over the brush assist the catching of silt. After the first layer of brush is covered with silt, other layers can be placed on top until the gully is filled. This practice is especially applicable for filling the lower end of a gully where the fall is not great.



B. P. R. D-3246

FIG. 15.—Newly constructed woven wire fencing dam built to control erosion at head of gully. Near Alma, Wis.

WOVEN-WIRE DAM.

It is common to see drift and silt collected above a woven-wire fence that extends across a draw in a field. In this way, perhaps, the idea of the woven-wire dam originated. Like the brush dam, the woven-wire dam is found in every section of the United States.

A woven-wire dam consists essentially of a low fence across a gully, the difference being that the posts must be set closer together and anchored solidly upstream where the force of the water is great. The common method of building these dams consists in setting a row of ordinary fence posts across the gully about 4 feet apart. The

posts should be set at least 4 feet deep and should be anchored by wire to anchor posts driven 8 or 10 feet above the line of the dam. These anchor posts are later covered with the deposit of soil caught by the dam, which greatly increases their holding power. The end posts should be set in a trench dug into the sides of the gully. The best results are obtained when a trench is dug along the upper side of the posts so that the woven wire may be fastened 6 inches or a a foot below the surface. The woven wire should be at least 30 to 36 inches wide and should be set into the ground so that about 2 feet extend above the surface. The wire is fastened to the upper sides of the posts, and the trench in the sides and across the gully is filled up and carefully tamped. When there is not enough trash in the water to close the large meshes in the wire and catch the soil particles, a little straw, leaves, or fine brush can be placed against the upper side of the wire to get a fill started. Angle-iron posts are sometimes used instead of wooden posts (see fig. 15).

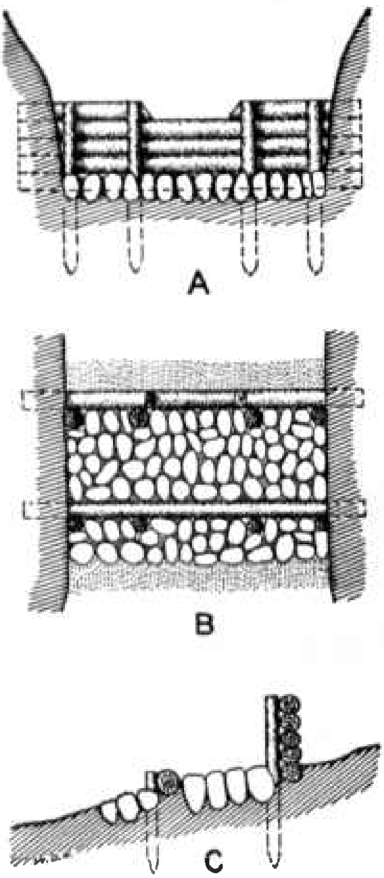


FIG. 16.—Dam built of logs and posts with spillway at center and stone pavement below the dam. *A*, Front view. *B*, Top view. *C*, Side view.

A dam of this type is especially suitable for use in gullies with moderate slopes and small drainage areas. It is very effective in checking head erosion at the upper end of the gully.

LOG DAM.

In a country where timber is abundant log dams are very commonly built to check gully erosion. The simplest dam for small, narrow gullies is made by placing a large log in a shallow trench across the gully. The trench is cut into the sides of the gully so that the ends of the log extend into both sides. Other smaller timbers about 6 or 8 feet long are laid close together lengthwise of the gully, with the downstream ends resting on the log and the other ends on the bottom of the gully above the

log. The timbers are spiked to the log. Old railroad ties are sometimes used for the timbers. Dams built in this manner have been very successful in filling gullies draining small areas.

Another type of log dam rather simple to construct is built as follows: Posts are set in a row across the gully 4 feet apart, about 4 feet deep, their tops extending 3 or 4 feet above the bottom of the gully. A trench is then dug on the upstream side of the posts extending about 2 feet into the sides of the gully. A log is laid in this trench, which is just about deep enough to bury the log, and other logs are laid on top of the first, until the top log is as high as the top of the posts. The logs are held in place by piling dirt against them or by driving small stakes on the upper side at the ends of the logs, or they are spiked to the posts. A section of the top log between the two posts nearest the center of the dam is cut out to provide a way for the water to flow over the dam and prevent washing around the ends (fig. 16). The bottom of the gully should be paved with stone for a distance of about 4 feet below the dam, or it may be protected from erosion by laying small logs together as a floor, holding them in place by stakes driven along the lower side. Where rock is plentiful loose rock is placed below the dam to prevent erosion by the falling water. Unless one of the above methods is employed there is likelihood of undermining the dam.

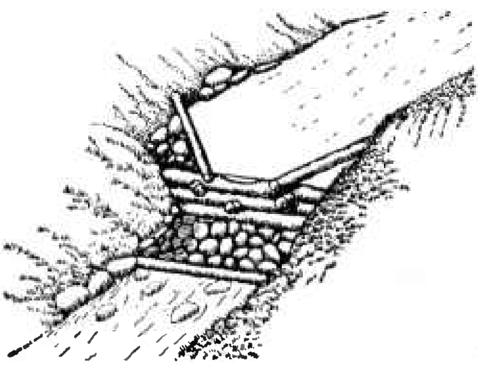


FIG. 17.—Log dam held by notched logs extending obliquely into the sides of the gully.

Where it is difficult to drive or set posts in a gully the logs may be held in place by other logs laid obliquely across them with the ends notched to fit into corresponding notches between the logs of the dam. The free ends of the oblique logs are covered with dirt, and their hold becomes stronger as the fill above the dam increases in depth (fig 17).

Where both timber and stone are plentiful, crib dams are sometimes built. The crib dam consists of a framework or box of logs across the gully, filled with rock fragments or stones. The ends extend into the sides of the gully, and the dam is built in a trench dug across the bottom. Undermining is prevented by a pavement of stone below the dam.

WILLOW-POST DAM.

Willow posts cut from green willow trees are used very effectively to fill gullies. They are set 2 or 3 feet apart in rows across the gully, sometimes several rows of them close together. Where there is plenty of water the willow posts take root and grow, forming a hedge across the gully. Trash and silt are caught above this hedge, causing a fill of soil. Straw or loose small brush may be thrown above the willows to assist in getting a fill started.

When quicker results are desired, a row of willow posts, 3 or 4 feet apart, is set across the gully, and railroad ties or logs are laid one on

B. P. R. D-3947

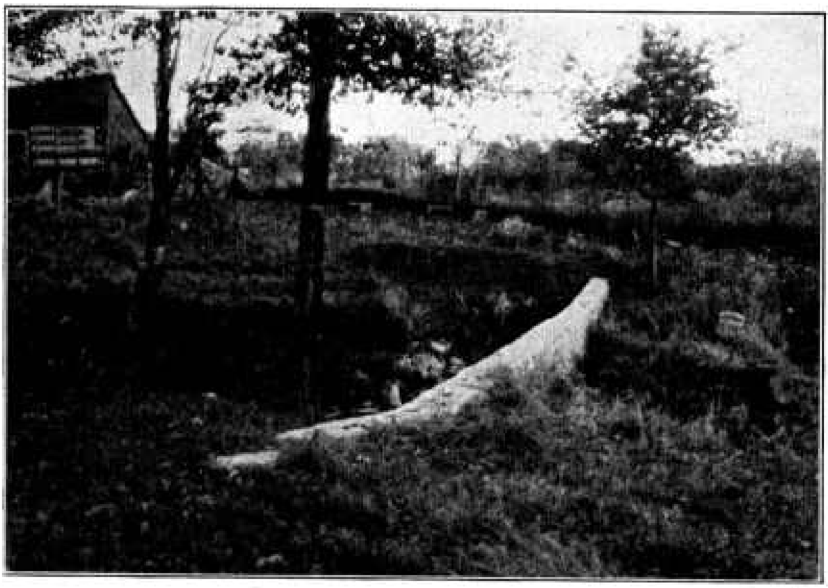
FIG. 18.—Upper side of a loose rock dam across a gully. A fill of 2 feet has occurred where the man is standing. Near Franklin, Tenn.

top of another above the posts in a manner similar to that described for log dams. Willow dams are usually built at the lower ends of gullies near main watercourses or where the soil is naturally moist throughout the year, for the rapid and thrifty growth of willows depends upon abundant water.

LOOSE-ROCK DAM.

Rock is a very good material for building low soil-saving dams. Its use is particularly advisable on farms where rock is plentiful and often a nuisance in the fields. Loose-rock dams should not be more than 2 to 3 feet high and should be built only in gullies of moderate slope and small drainage areas. The dam should be 4 or 5 feet wide

at the base and about 2 feet wide on top. The rock should be so arranged that the small pieces fit in among the large. Only large pieces should be used on the top of the dam, as a current of water has often sufficient force to move even large stones. The dam should be built well into the banks of the gully and should be lowest in the middle. A trench about 6 inches deep should be dug across the gully, in which the foundation of the dam, consisting of the largest rock, should be laid. The gully below the dam for about 5 feet should be covered with loose rock to prevent erosion and the undermining of the dam. Figure 18 is a view above a loose-rock dam that has caught a fill of about 2 feet.



B. P. R. D-3880

FIG. 19.—Masonry dam built across a gully draining over 1,000 acres. This dam extends well into the banks and lower in the middle than at the ends. Near Kansas City, Mo.

STONE-MASONRY DAM.

Masonry dams are usually built instead of loose-rock dams where a greater height than 3 feet is desired, where the flow in the gully is large, or where rock is not plentiful and its economical use is necessary. The construction of the dam is similar to that of a masonry wall, and the sides should have a batter of 1 in 5 or 1 in 10. The thickness of the dam at the bottom should be about one-half the height, and the base should be 1 to 2 feet below the bottom of the gully for dams 3 to 6 feet high. Dams of this kind higher than 6 feet are not recommended unless an excellent foundation be obtained, special precautions be taken against undermining, and the walls be extended far enough into the banks of the gully to prevent cutting

around the ends. The services of an engineer would be required to build a high masonry dam, and hardly any two gullies would require the same design.

For dams 3 or 4 feet high the water may be made to flow over the central portion of the dam by gradually increasing the height of the dam from some point near the middle toward the ends, as shown in figure 19. Where the ends of the dam are extended well into the banks, it is not necessary for the base at the ends to be as low as the base across the gully. Loose rock should be placed below the dam to prevent washing and undermining.

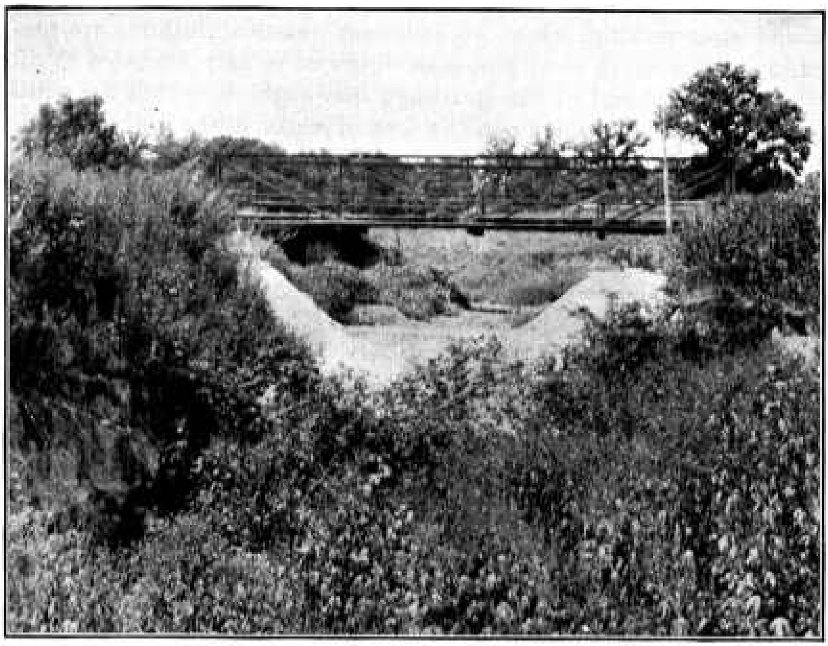
A dam higher than 4 feet should have a notched spillway in the middle that confines the overflow water to the middle portion of the dam, and a carefully paved floor should be prepared below the spillway to prevent undermining by the falling water. Masonry dams more than 3 or 4 feet high are not much used in the reclamation of gullies, owing to the high cost and the difficulty of making them secure.

CONCRETE DAM.

Concrete dams are frequently employed in all sections of the country to control and fill in gullies. It must be said that results have been generally far from satisfactory. Failures are common and may be attributed to both poor design and faulty construction, generally due to the desire to keep the cost low, or to inadequate conceptions of the erosive action of moving water and the pressure exerted by standing water. Where concrete dams have been properly designed and constructed good results have been obtained.

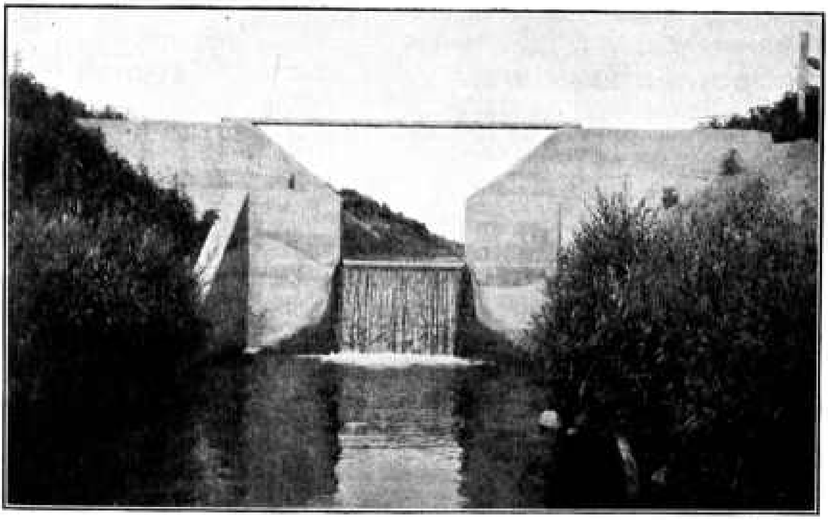
In building concrete dams provision should be made for passing the water over the dam, without injury to the structure, by providing for a spillway, usually over the middle of the dam. If the dam is level on top, with no spillway, the water flowing over the entire dam will invariably cut the earth away around one or both ends, and a channel will be formed for the passage of the water around the end of the dam, which will also allow the accumulated silt to escape. In conjunction with the spillway the sides should extend to the top of the gully or as high as it is expected that the water will rise in the gully, so that the water can not come in contact with the sides of the gully (fig. 20). The ends of the dam should extend far enough into the sides of the gully to prevent seeping of water around the ends, which often results in a washout.

In figure 21 is shown a properly designed reinforced concrete dam with spillway, suitable for gullies draining large areas. The abutments extend well into the banks as high as the top of the ditch. The buttresses, one on each side of the spillway, give support to the dam and confine the water so that it falls on a concrete floor ex-



B. P. R. D-3114

FIG. 20.—Concrete dam across large gully with sides of spillway extending to top of the banks of the gully. This dam was built to fill the gully and prevent enlargement where the highway bridge crosses. A fill of 8 feet has occurred above the dam. Near Mason City, Ill.



B. P. R. D-4125

FIG. 21.—Reinforced concrete dam with spillway and concrete apron below, suitable for use in gullies that drain large areas. Cerro Gordo County, Iowa.

tending between and to the ends of the buttresses. Thus overturning and undermining, which are common causes of failure, are prevented. A dam such as is shown in figure 21 is only intended to fill the gully to the crest of the spillway; the height to which the spillway can be built depends upon the flow of water in the gully. If the fill in the gully is made too deep there is danger of the water overtopping the banks of the gully and the entire dam.

In figure 22 are shown the plan, elevation, and side view of a reinforced concrete dam recommended by the agricultural extension department of the Iowa State College. It is claimed for this dam that "it has a firm foundation, extends well into the banks, has an adequate spill platform, is built with the water, and has a means

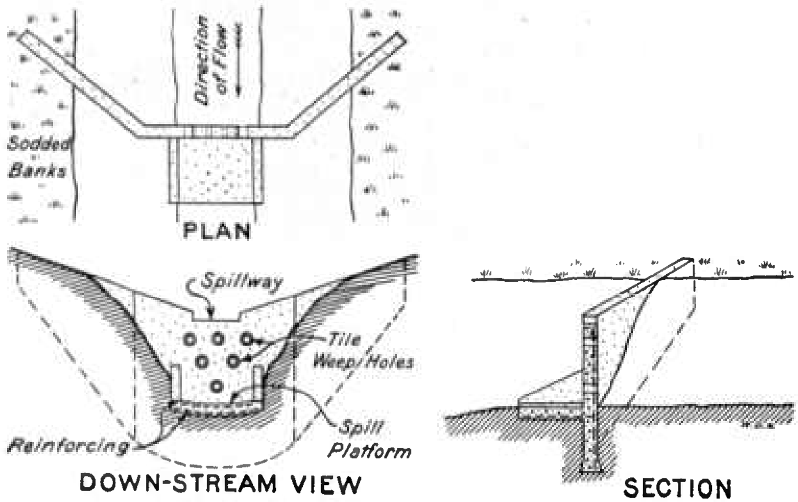


FIG. 22.—Plan, section, and downstream view of a concrete dam especially designed to guard against the common causes of failure.[1]

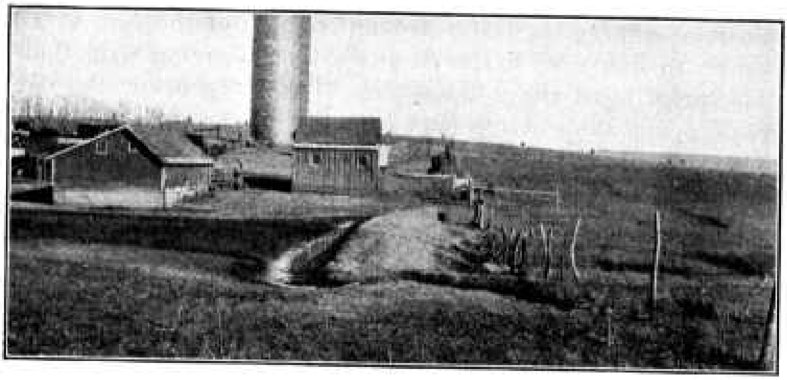
of relieving the water pressure." This design was proposed by the extension department after making comprehensive investigations of concrete dam failures throughout the State of Iowa, and it especially guards against the common causes of failure.

Concrete dams are built of either plain or reinforced concrete. Dams not exceeding 3 or 4 feet in height are usually built of plain concrete and higher ones of reinforced concrete. Failures often occur as a result of poorly made concrete. A good concrete mixture is 1 part cement, 3 parts sand, and 6 parts stone or broken rock. The services of a competent engineer should be engaged for the design and construction of a reinforced concrete dam. No one design could be given that is applicable to all conditions.

[1] From Bul. 80 of the Iowa State College Agr. Ext. Dept.

EARTH DAM.

Earth dams of two different types are used. In one type the surplus water is carried around or over the dam by spillways, and in the other it is carried through the dam by a pipe. In many installations the principles of both types are employed. Earth soil-saving dams are generally employed to fill very large gullies, though they are growing rapidly in favor for use in small gullies, particularly where no other cheap material is available for the construction of low dams.



B. P. R. D-8432

FIG. 23.—Earth soil-saving dam which has filled a deep gully. The fill is drained by a tile extending through the dam into the gully below. Near Red Oak, Iowa.

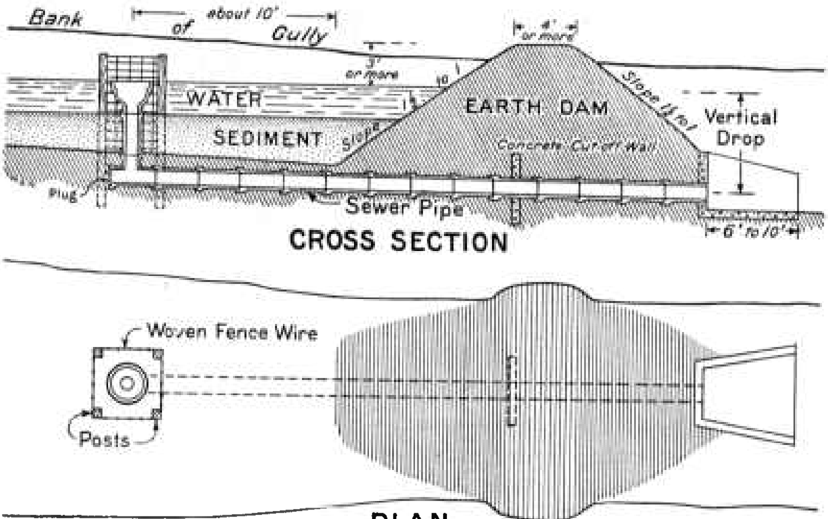
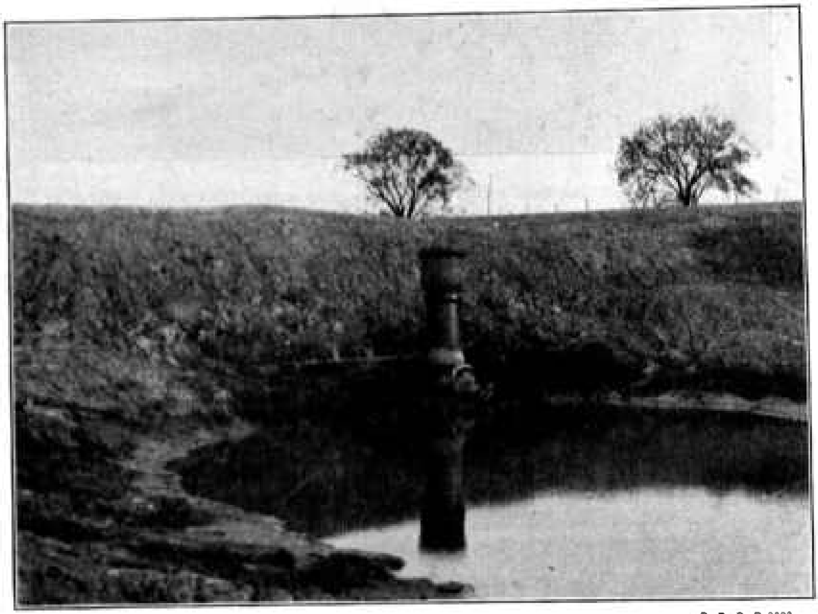


FIG. 24.—Drop-inlet and earth soil-saving dam.

If a spillway is used to carry the water around or over the dam, a pond is formed above the dam, and if the capacity of the pond is not

sufficient to hold the greatest run-off of water from the drainage area the surplus water is conducted by a channel around one end of the dam, as shown in figure 23, or it may be carried over the dam in a sheet-metal or plank flume. Because of the chances of injury to the dam, the latter method is not recommended, however, unless it is impossible to carry the water around one end of the dam over firm ground. In figure 23 is shown an earth soil-saving dam that has satisfactorily filled the gully above. The gully below the dam is quite deep, and the water is kept out of it by carrying it around the dam and emptying it into a watercourse of the adjacent watershed. The fill above the dam has been drained with tile through the dam



B. P. R. D-3903

FIG. 25.—Vertical inlet pipe newly constructed, showing hopper pipe on top and end of T plugged with vitrified clay stopper cemented in the pipe. Near Marshall, Mo.

into the gully below, so that now there is good farm land where formerly a gully existed, and the advance of the gully through the farmer's barn lot has been stopped.

In the other type of earth soil-saving dam vitrified sewer pipe is generally used to carry the water through the dam. A cross-sectional view of a dam of this type is shown in figure 24. Water from heavy rain fills the basin above the dam, the silt settles to the bottom of the basin, and the water flows through the vertical inlet pipe and the pipe through the dam into the gully below the dam. When the basin is filled to the top of the inlet pipe another section of pipe may be added and the filling continued. The top of the inlet pipe should be at least 3 feet below the top of the dam, and where conditions

permit the top of the dam should be at least 1 foot higher than the firm ground on the sides of the gully after the dam has settled, so that if an unusual rain occurs—a heavier rain than the pipe can handle—the water will flow over the firm ground, not over the top of the dam. The vertical inlet pipe should preferably be set 10 feet or more from the inside toe of the dam, because at that distance it is not likely to become clogged with floating trash that usually accumulates near the dam and there is less danger of eddying water around the inlet pipe causing a break in the dam. Nevertheless the usual practice is to set the inlet pipe close to the dam, because less pipe is required. This practice is no doubt responsible for a great many failures.

Another precaution against possible clogging of the inlet pipe is to wrap ordinary woven fence wire round four posts set around the pipe so that the bottom of the wire is a little lower than the top of the inlet pipe. This permits the water to pass but keeps out the floating trash. Where it is desired to keep the gully drained above the dam and prevent the formation of a pond, the vertical inlet pipe is joined to the horizontal pipe by a tee connection, and to one end of the tee is connected a drain pipe that extends up the gully.

In many instances farmers desire to make the dam serve the double purpose of filling the gully and furnishing a watering place for stock. In such cases an elbow connection is used in place of the tee, or the end of the tee is plugged with a vitrified clay stopper cemented in the pipe. A foundation of stone or concrete should be provided for the tee or elbow of the inlet pipe to rest upon. The flow of the water into the vertical inlet pipe can be facilitated by placing a hopper pipe on top of the vertical inlet (fig. 25).

The pipe through the dam and the joints of the vertical inlet pipe, with the exception of the top one, should be cemented. Great care should be used in laying the pipe through the dam. A trench with enough fall to prevent water from standing in the pipe should be dug in the bottom of the gully, and holes should be dug under the bell of each pipe so that the barrel rests on firm ground. After the joints are cemented and dried, clay soil should be placed around the pipe and thoroughly tamped. Tamping should be continued over the pipe until it is covered with 2 or 3 feet of soil. Unless the soil forms a close bond with the pipe, seepage of water along the pipe is likely to occur, which often washes a hole through the dam (fig. 26). Seepage along the pipe can be prevented by building a concrete cut-off wall at the middle of the dam as shown in figure 24. If a firm and even foundation for the pipe is not obtained a little unequal settlement due to the weight of the earth above may cause leakage by breaks in the joints of the pipe.

Some sort of protection against erosion should be provided where the water discharges from the outlet pipe into the gully below. More important than preventing erosion of the gully below the dam is the prevention of undermining and eating-back through the dam along the pipe. In figure 24 is shown a channel built of concrete to stop erosion at the outlet of the tile. This channel is usually made 6 to 10 feet long, depending upon the vertical drop of the water. The greater the vertical drop the greater will be the velocity and eroding power of the water. Where it is desired to keep the water out of the gully below the dam the tile can be extended beneath the ground down through the gully to a suitable outlet.

B. P. R. D-3902

FIG. 26.—Results of water seeping along outside pipe through a dam.

Under "Outlets for Soil-saving Dams" (p. 38) the size of outlet pipe required is thoroughly discussed and in Table 1 are given the sizes of pipe to use for soil-saving dams. Where the pipe used is too small, overtopping and washing out of the dam generally occur.

After the location for the dam is chosen the foundation should be prepared by clearing away all weeds, growths, and débris and plowing the site to reduce the possibility of seepage along the bottom of the dam. Another precaution against seepage which it is often advisable to observe, especially where the dam is 10 feet or more in height, is to dig a trench the length of the dam 6 to 10 feet wide and 1½ feet deep. The sides of the trench should be made vertical so as to break the seam between the natural ground and the dam, and the bottom of the trench should be plowed. The dam should be built in layers about 1 foot in depth. It is usually built with teams and scrapers, the material being tamped and compacted by the horses' feet and the scrapers. The best results are obtained when the loose earth is

sprinkled with water, which facilitates the compacting of the embankment and makes it more impervious. The top of the dam should be not less than 4 feet wide, the side slopes on both faces of the dam not less than $1\frac{1}{2}$ horizontal to 1 vertical. The top of the dam should be not less than 3 feet above the bottom of the spillway or top of the vertical inlet pipe. In figure 24 is shown a section recommended for an earth soil-saving dam.

The best material for building an earth dam consists of 1 part clay to 2 or 3 parts gritty earth. Where water is not available for dampening the material it is best to construct the dam during the rainy season so that the earth in the borrow pit may be kept damp by rains. Material for building dams should preferably be taken from above

B. P. R. D-3378

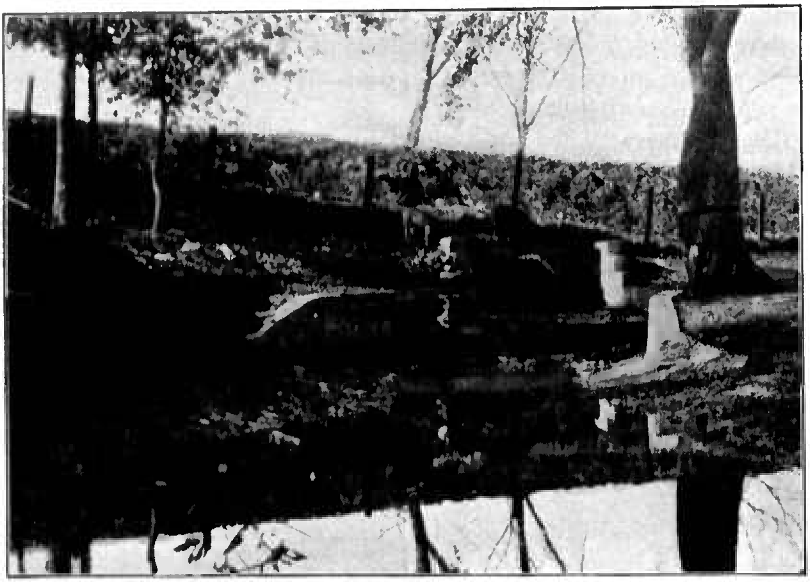
FIG. 27.—Earth soil-saving dam with roadway across the top. The vertical inlet is a concrete structure 5 feet wide by 10 feet long with 3 30-inch sewer pipes. The outlet ends of these pipes are shown in figure 28. Near Kansas City, Mo.

the dam, 20 to 25 feet above the upstream toe. An allowance of about 10 per cent should be made for the settlement of the material in the earth embankment.

Where the top of the earth dam is used as a roadway it should be at least 8 feet wide. In figure 27 is shown a private road across an earth soil-saving dam. This roadway is 12 feet wide and affords a very convenient means of crossing the wide depression in the field. In figure 28 is shown the outlet end of the same dam.

The popularity of the drop-inlet, earth soil-saving dam is growing rapidly. In Saline County, Mo., several hundred have been built, one farmer having 14 on his farm. In this county they are made in

small as well as large gullies and are placed one above another in the same gully so that the fill from one reaches nearly to the outlet of the next dam above (fig. 29).



B. P. R. D-3877

FIG. 28.—Outlet end of dam shown in figure 27. Note the substantial head wall and the concrete floor below to prevent erosion and undermining. Near Kansas City, Mo.

B. P. R. D-3909

FIG. 29.—Two large earth soil-saving dams in one draw where formerly a gully existed. Near Warrensburg, Mo.

DROP-INLET HIGHWAY CULVERTS.

In many sections of the country gullies are a source of much trouble and expense in the construction and maintenance of public highways. Bridges are required to cross them, and where the gullies are growing wider the length of the bridges must constantly be increased. A notable example is a bridge over a gully near Falls City, Nebr. Twenty-five years ago the gully did not touch the road; since then it has crossed the road and continually widened. A trestle 185 feet long crosses the gully, and its length has been repeatedly increased as the abutments for the approach spans have been undermined by the caving in of the sides of the gully from time to time. The drainage

B. P. R. D-3447

FIG. 30.—Highway bridge to be replaced by an earth embankment and a combined culvert and concrete drop inlet. Near Winterset, Iowa.

area above this bridge is only about 70 acres, the water from which could be readily removed by a moderate-sized culvert. In this case further erosion could be stopped by building a road embankment with combined concrete drop-inlet and culvert as shown in figure 30.

In figure 31 is shown a close view of a concrete drop-inlet, and in figure 32 is shown its design, which was furnished by E. B. Hiatt, county engineer, Madison County, Iowa. The cover over the drop-inlet prevents animals from falling in. This cover interferes with the flow to some extent. In place of the cover a fence may be built to keep animals out. In figure 33 is shown a fill of soil 8 feet deep above a road embankment in what was formerly a deep gully. The fill extends to the top of the drop inlet. The top of the roadway

should be 4 or 5 feet higher than the top of the inlet pipe as a factor of safety against overtopping the embankment after heavy rains.

FIG. 31.—Drop inlet and box culvert. Plan shown in figure 32. The old wooden bridge is to be replaced by an earth fill.

Gullies of the waterfall type often eat their way slowly up a watercourse toward a highway. Generally no attempt is made to check the gully until it has reached the road. The usual method then employed to stop the gully from crossing the roadway is to build a concrete structure to prevent further erosion of the gully and the undermining of the roadway and culvert. Figure 2 (p. 5) shows such a structure built at a great expense to the county. At the time the picture was taken the structure was partly undermined. About a year after the work was completed the roadway and structure were washed out. The failure was due to a poor foundation and to the concrete not extending far enough from the culvert. Where such structures are required they should be properly designed and carefully constructed. It is

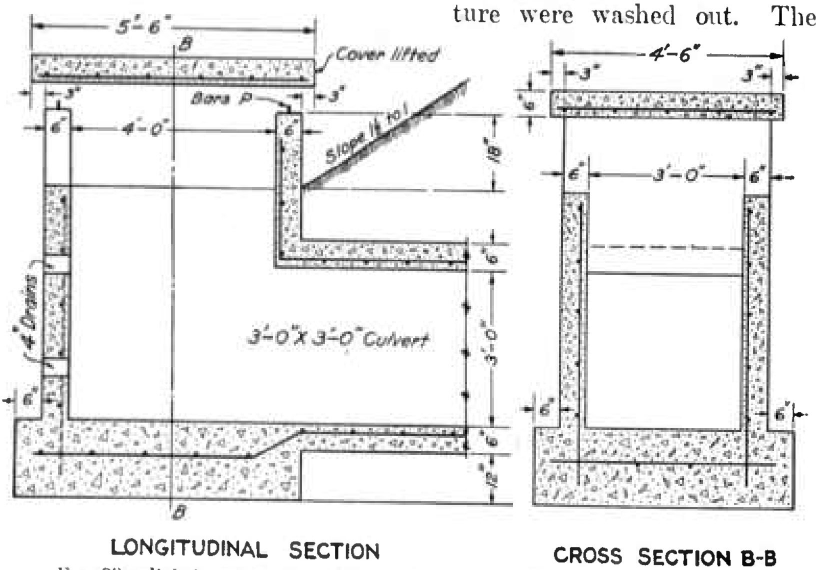
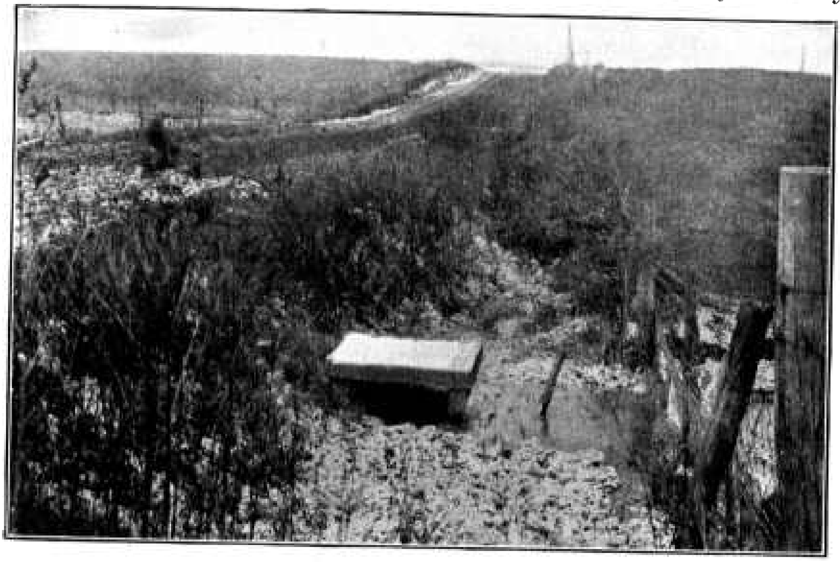


FIG. 32.—Reinforced concrete drop inlet for box culvert[1] shown in figure 31.

[1] Designed by E. R. Hiatt, county engineer, Winterset, Iowa.

invariably more satisfactory and inexpensive to stop the gully in the farmer's field before it has reached the roadway.

In building a road embankment to cause a fill in the gully above by



B. P. R. D-4122

FIG. 33.—Fill of soil 8 feet deep, extending to the top of the drop inlet, taken one year after the completion of the work. Near Winterset, Iowa.

the use of the drop inlet more care should be taken than in building an ordinary embankment not subject to water pressure from above. The best material should be placed and carefully tamped around the barrel of the culvert and on the upstream side of the embankment. Where it is difficult to make a satisfactory bond between the earth and the concrete culvert, one or two concrete cut-off walls should be built around the barrel of the culvert to prevent seepage along it.

B. P. R. D-3489

FIG. 34.—Road embankment and concrete drop inlet replacing an old bridge that was 60 feet long and 35 feet high. Depth of fill is 12 feet. Near Falls City, Nebr.

A great many of these concrete drop inlets have been built by Mr. Hiatt and by J. F. Relf, county engineer, Richardson County, Nebr. An installation from which excellent results have been obtained is shown in figure 34. In this case a long highway

bridge was replaced by an earth embankment and a deep gully was filled to the top of the drop inlet.

The kind of inlet used in Richardson County, Nebr., is shown in figure 35. From the crest of the inlet to the bottom of the culvert the wall is made sloping so as to give the water at entrance a direction of flow conforming more nearly to that of the flow through the culvert than is the case for an inlet with vertical walls. No cover is placed over the inlet, as it is especially designed to facilitate the entrance of the water. This type of inlet is quite commonly added to existing concrete culverts where it is desired to fill a gully above a road embankment.

In the above-named counties many landowners have shown a desire to cooperate by sharing in the expense of building the drop-inlet

B. P. R. D-3449

FIG. 35.—Concrete drop inlet with sloping wall from crest to bottom of culvert to facilitate entrance of water. Near Falls City, Nebr.

culverts. In this way many old wooden bridges are being replaced by earth embankments and many gullies are being filled and reclaimed for production.

OUTLETS FOR SOIL-SAVING DAMS.

The chance against failure of a soil-saving dam depends primarily upon the adequacy of the outlet. The outlet may be a spillway that carries the water over or around the end of the dam, a pipe or conduit that carries the water through the dam, or often a combination of the two. The rate at which the water should be carried depends upon the size, shape, and topography of the watershed area, upon the quantity of water that can be stored by the dam, and upon the intensity and amount of heavy rains.

Table 1.—Cross-sectional areas of pipe or conduit for drop-inlet, soil-saving dams for rolling watersheds with length equal to about twice the width.

Drainage area.	With no spillway around or over dam. Very little storage above dam. 4-foot drop.	8-foot drop.	Storage above dam, surface area, ½ acre at level of top of inlet pipe. 4-foot drop.	8-foot drop.	With spillway having capacity about half that of pipe in column 2; storage, ½ acre at level of top of inlet pipe. 4-foot drop.	8-foot drop.
Acres.	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*
1	0.4	0.3	0.2	0.1	0.05	0.0
2	.7	.5	.35	.2	.1	.0
4	1.1	.8	.6	.3	.15	.0
6	1.5	1.1	.8	.5	.2	.0
8	1.9	1.4	1.1	.65	.25	.0
10	2.2	1.7	1.3	.8	.30	.0
15	3.0	2.3	2.0	1.2	.4	.1
20	3.8	2.8	2.7	1.7	.5	.2
25	4.5	3.4	3.4	2.2	1.1	.3
30	5.1	3.8	3.9	2.6	1.2	.5
35	5.8	4.3	4.5	3.1	1.5	.7
40	6.3	4.8	5.1	3.5	1.8	1.0
45	6.9	5.2	5.7	4.0	2.2	1.2
50	7.5	5.6	6.3	4.4	2.6	1.5
60	8.6	6.5	7.6	5.4	3.2	2.2
70	9.7	7.3	8.6	6.2	3.7	2.5
80	10.7	8.0	9.6	6.9	4.2	2.9
90	11.7	8.8	10.6	7.7	4.8	3.3
100	12.6	9.5	11.6	8.4	5.3	3.7
125	15.0	11.2	14.1	10.4	6.7	4.8
150	17.2	12.9	16.7	12.4	8.2	6.0
175	19.2	14.4	19.2	14.4	9.6	7.2
200	21.3	16.0	21.3	16.0	10.6	8.0
300	28.8	21.6	28.8	21.6	14.4	10.8
400	35.8	26.8	35.8	26.8	17.9	13.4
500	42.3	31.7	42.3	31.7	21.1	15.8
600	48.5	36.4	48.5	36.4	24.2	18.2
700	54.4	40.8	54.4	40.8	27.2	20.4
800	60.2	45.2	60.2	45.0	30.1	22.5
900	65.7	49.3	65.7	49.2	32.8	24.6
1,000	71.1	53.3	71.1	53.3	35.6	26.6

For very hilly watersheds increase above cross-sectional areas 25 per cent.
For square or fan-shaped watersheds increase above cross-sectional areas 15 per cent.
For sizes of pipes corresponding to the above cross-sectional areas see Table 2.

Table 2.—Cross-sectional areas of pipes of standard diameters for use in selecting sizes corresponding to areas in Table 1.

Diameter of pipe.	Cross-sectional area of pipe.	Diameter of pipe.	Cross-sectional area of pipe.
Inches.	*Sq. ft.*	*Inches.*	*Sq. ft.*
6	0.20	27	3.98
8	.35	30	4.91
10	.55	33	5.94
12	.79	36	7.07
15	1.23	39	8.30
18	1.77	42	9.62
21	2.41	45	11.04
24	3.14	48	12.57

In concrete or masonry structures provision should be made for the water to flow over the entire length of the dam in case of unusually heavy rains. The sides of the dams should be extended as high as the banks of the gully or as high as the highest water expected in the gully.

In the case of earth soil-saving dams a spillway should always be provided around one or both ends of the dam, where possible, by building the top of the dam higher than the natural firm ground on either side of the gully. The greater this height the greater will be the factor of safety against the dam being overtopped and washed out. Spillways built of hard material over the tops of earth dams are not recommended, because of the difficulty of maintaining them and the danger of undermining at their lower end.

It is important that the pipe through a drop-inlet soil-saving dam be made large enough to provide for the removal of heavy rainfalls rapidly enough to prevent overtopping. In Table 1 are given the sizes of pipe or conduit adapted to specified conditions. This table is based upon observations of soil-saving dams that are giving satisfactory service and upon areas drained by culverts through highway and railroad embankments. In column 2 are given the cross-sectional areas of a pipe or conduit required for a soil-saving dam where no spillway is provided for the water to flow over or around the dam, where the storage above the dam is very small, as in a narrow valley with a steep slope, where the drop from the top of the inlet pipe to the center of the outlet end of the pipe through the dam is 4 feet, and where the watershed above the dam is rolling and about twice as long as wide.

In column 4 are given the cross-sectional areas required where the conditions are the same as for column 2 except that considerable water is stored above the dam, which has the effect of reducing considerably the size of pipe required for small watersheds, but very little for watersheds 100 acres or more in extent. The surface area of the

water stored is assumed to be one-half acre. The area of conduit required can be increased or decreased according as the surface area of the water stored is less or greater than one-half acre.

In column 6 are given areas required where the conditions are the same as for column 4 except that provision is made to carry water over a spillway around the dam with a capacity equal to one-half of the capacity of pipes or conduit with areas as given in column 2. With a depth of about $1\frac{1}{2}$ feet of water in the spillway, to remove through it the same amount of water as will be passed by a drop inlet with 4 feet drop, the cross-sectional area of the spillway should be from four to eight times that of the drop inlet, depending upon the distance the water would have to flow to go around the end of the dam and back into the gully below; the greater this distance the less will be the flow of the water. The spillway capacity can be increased as desired by increasing the height of the dam.

Suppose it is desired to know the size of a pipe or conduit required for a rolling watershed of 25 acres with length equal to about twice the width, where the surface area of the water stored above the dam would be about one-half acre, where no provision would be made for a spillway round or over the dam, and where the vertical drop from the top of the inlet to the outlet end of the pipe would be 8 feet. In the first column in Table 1, under "Drainage area in acres," find 25, then follow the line across the page to the right to the fifth column, which falls under three heads at the top of the table. First, no spillway round or over dam; second, storage above dam, surface area one-half acre at level of top of inlet pipe; third, 8 feet drop. The number in the fifth column is 2.2, which means that the pipe through the dam should have an area of 2.2 square feet. In Table 2 it is found that an 18-inch pipe has a cross-sectional area of 1.77 square feet and a 21-inch pipe 2.41 square feet. A 21-inch pipe should be chosen, since no smaller standard-sized pipe is made which has the required area.

Where several drop-inlet, soil-saving dams are built in a gully, the outlet pipe for the upper dam should be chosen as explained above. The size of the outlet pipe for the next dam below will depend upon several governing conditions: (1) If the storage above the upper dam and the additional watershed area drained by the gully between the dams are negligible, the outlet pipe for the lower dam should be of the same size as for the upper dam; (2) if the storage above the upper dam is negligible and there is a large additional watershed area between the dams, then the size of the outlet pipe should be chosen from Table 1 for the total watershed area above the lower dam; (3) if there is considerable storage above the upper

dam and a negligible watershed area between the dams, the pipe for the lower dam might be smaller than for the upper dam, yet on account of the difficulty of ascertaining just how much smaller the pipe could be, a safer practice would be to use the same size of pipe for both dams; (4) if there is considerable storage above the upper dam and a large watershed area between the dams, the outlet pipe should be chosen from Table 1 for a watershed equal to the sum of the watershed area between dams and a certain part of the watershed area above the upper dam, depending upon the reduction in flow effected by the upper dam storage. It is impossible to say just what part of the upper watershed should be included, since hardly any two cases would be similar, but this information can be obtained from an engineer after an examination of the watersheds and the dam sites.

The waterway through the dam may be a pipe or a concrete box. Standard vitrified clay sewer pipe can be obtained up to 36 inches and concrete pipe up to 48 inches in diameter. Where a cross section greater than that of a 36 or 48 inch pipe is required a concrete conduit of the required cross-sectional area can be built.

Where the outlet pipe is extended down the gully as an underdrain, a very good practice since it prevents erosion at the outlet and in the gulley below, a somewhat larger tile would be required than that indicated in Table 1, the size of which should be determined by an experienced engineer.

HOW TO RECLAIM A GULLY WITH SOIL-SAVING DAMS.

Before beginning work a plan should be decided upon for the reclamation of the entire gully. Too often a small section of a gully is reclaimed in a way which will not fit into any later scheme for the reclamation of the whole gully. Attention should first be directed to the upper end, where head erosion is going on. This should be stopped by building an overfall of brush and straw, as has been described, by constructing a flume for conducting the water into the gully without erosion or by the diversion of the water from the head of the gully.

Next, plans should be made for filling the gully. If the gully decreases gradually in depth toward the lower end and terminates in a wide, shallow depression, a number of low, temporary dams can be used. If the gully terminates in the side of a deep drainage channel, however, the lower end can not be filled by a low dam, and a high one must be built where the gully enters the channel. Although the higher the dams the fewer that will be required to fill a gully, yet unless conditions make it necessary to use high dams low ones should be used, since the cost will be less, and low dams are much less subject to failure.

Often the erosion of soil from the watershed is very slight, and a number of years would be required to fill the gully. This is especially the case where the watershed is in pasture, meadow, or timber. In such cases a series of dams of the overflow type should be built, so that some silt will be caught above each one, or a dam may first be built at the lower end of the gully and other dams later built in succession above after the gully is partly filled in. The side slopes of the gully should be plowed in, so that farming operations can be conducted in and across the gully.

Some gullies occur in the natural drainage channels of fields and have large drainage areas, while others occur on the slope of a hillside with very small drainage areas which are not well defined. Gullies of the latter type may be entirely filled and then prevented from washing out by proper cultural methods or by terracing. Gullies with large, well-defined drainage areas can not be entirely filled, since it is necessary that a waterway be left large enough to carry the water from the watershed. A very common mistake is so to reduce the size of the waterway by filling in the gully that the drainage water overflows the banks of the gully; this often proves disastrous to reclamation works. The size of the waterway that should be left can be judged from the high-water flow in the gully due to the heaviest rains that have occurred in the past.

SPACING DAMS IN A GULLY.

In reclaiming the whole length of a gully a series of dams is built along its length, the distance between the dams depending upon their height and the slope of the gully. The less the slope of the gully or the greater the height of the dam the greater may be the distance between the dams. Usually the dams should be so spaced that the fill that accumulates to the top of one dam extends to the foot of the next dam above. A dam will cause a fill that is higher at some distance above than at its foot. The fall of the surface of the fill in the gully will not much exceed 6 inches in 100 feet, and in computing the distance between dams so that the fill will extend from the top of one dam to the foot of the next this rate of fall has been assumed and values for Table 3 were computed accordingly. The table gives the distances between dams in a gully for dams ranging from 2 to 10 feet in height and for gullies with falls ranging from 2 to 20 feet in 100 feet.

Table 3.—Distances between dams in gullies for dams of various heights and gullies of various bottom slopes.

Height of dam.	Bottom slope of gully.				
	2 feet in 100 feet.	5 feet in 100 feet.	10 feet in 100 feet.	15 feet in 100 feet.	20 feet in 100 feet.
	Distances between dams.				
Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
2	133	44	21	14	10
3	200	67	32	21	15
4	267	89	42	28	20
5	333	111	53	34	26
6	400	133	63	41	31
7	467	156	74	48	36
8	533	178	84	55	41
9	600	200	95	62	46
10	667	222	105	69	51

Sometimes there are contracted sections in gullies that are naturally suitable for the location of dams. Under such circumstances it may be desirable to disregard the spacing as given in the table and build the dams high enough to conform to the spacing naturally suggested. With the actual distances between the dams determined, the required heights can be taken from the table.

As a general rule it is cheaper and more satisfactory to reclaim gullies with low rather than with high dams. A low dam costs considerably less and requires less care and attention than a high dam.

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